TAILINGS BASIN RECLAMATION ATLANTIC CITY IRON MINE, WYOMING[1]

by

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Abstract: An 81 ha (200 ac) tailings impoundment at a taconite operation in Wyoming abandoned in 1985 has been a source of blowing dust. The site qualified for reclamation under Wyoming's Abandoned Mine Land program. The reclamation design included: incorporating commercially available organic amendments and fertilizers into a 300 mm (12 in.) thick "cap" of a sterile gravelly clay loam cover material, planting trees in the protective wind/snow shadows of rock berms and rock snow fences, lowering the water level in a flooded mine pit that was feeding uncontrolled seeps, and constructing a wide tailings pond spillway that allows flood control while minimizing seasonal water level fluctuations in the pond. The construction of the earthwork aspects of the design were completed over two construction seasons, including work during the winter at this high-altitude (2,470 m [8,100 ft.]) site. This occurred because snow from an early winter storm that collected behind the rock berms and rock snow fences was slow to melt. Furthermore, the increased snow catch made the site too wet the following spring to allow seeding during the normal seeding window; a fall planting was necessary. The rocky nature of the cover material prompted the development of innovative reclamation approaches, including fabricating a "rock rake" bulldozer blade and applying organic soil amendments by aerial spraying. A randomly-configured two-acre test plot was installed to evaluate the benefits of various soil amendments as the site matures. Future work on the site will include tree seedling planting and plugging of a decant pipeline.

Additional Key Words: revegetation, snow capture, wind protection, reforestation, organic soil amendments.

Introduction

The Atlantic City Iron Mine is located in Fremont County in central Wyoming, near the historic gold mining camps of Atlantic City and South Pass City. It lies on the southeast flank of the Wind River Mountains at an elevation of about 2490 m (8100 ft) above sea level. (See Figure 1.)

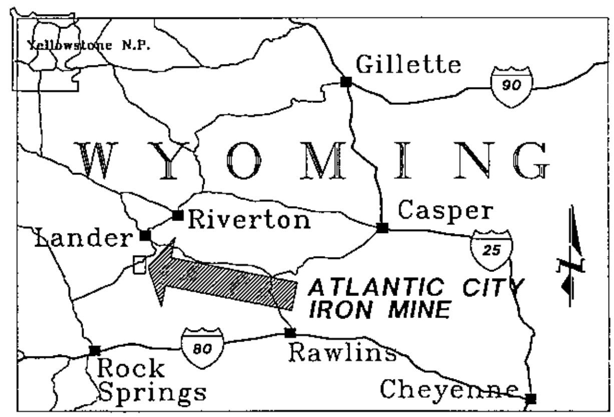

Figure 1. Site Vicinity

The Atlantic City Iron Mine was opened by US Steel in August, 1962 and it closed in 1983. Taconite iron ore was mined by surface methods; the ore was separated from the waste magnetically. The magnetic concentrate was mixed with bentonite, formed into pellets and roasted to produce a blast furnace feed stock for US Steel's blast furnaces in Geneva, Utah. The pellets were hauled by rail to the Geneva Iron Works.

[1]To be presented at the 16th National Meeting of the American Society for Surface Mining and Reclamation, August 13-19, 1999, in Scottsdale, Arizona

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Proceedings America Society of Mining and Reclamation, 1999 pp 184-191
DOI: 10.21000/JASMR99010184

https://doi.org/10.21000/JASMR99010184

The Atlantic City Iron Mine produced three basic types of wastes: waste rock overburden from mining, a coarse-grained (sand to small gravel sized), non-magnetic reject rock termed "cobbs" and fine-grained tailings ranging from 28 mesh to <200 mesh. The waste rock has been used as an aggregate/rip rap source by a local contractor and the Wyoming Department of Transportation (WYDOT). The WYDOT also utilizes the cobbs as a source of highway sand during the winter.

US Steel divested its interests in the Atlantic City Iron Mine following cessation of operations, including reclamation obligations under a permit from the Wyoming Department of Environmental Quality (DEQ), Land Quality Division. Subsequent legal actions and a judgment against the successor owner resulted in a large area of unreclaimed waste rock dump and tailings basin becoming eligible for reclamation under the Abandoned Mine Land Program of the Wyoming DEQ (WDEQ-LQD).

The Abandoned Mine Land reclamation program of the Wyoming DEQ was established under the Title IV provisions of the federal Surface Mining Control and Reclamation Act of 1977 (SMCRA). Wyoming AML's mission is to correct hazards to public health and safety and to correct off-site environmental degradation resulting from abandoned mines for which there is no environmental or reclamation responsibility. Wyoming AML's specific mission and goal for the Atlantic City Iron Mine is to implement a cost- effective permanent vegetative cover on the tailings basin surface to prevent a recurrence of the past blowing dust problem.

As shown on Figure 2, the tailings basin is confined by two dams. The north dam served to keep tailings from flowing into the mine pit, and was not constructed as a water impounding structure. The south dam is the primary tailings impounding structure, and it was built using both upstream and downstream construction methods. It stands about 61 m (200 ft) high from its base to its crest. After cessation of mining, the mine pit filled with water and has become locally known as Iron Lake.

Prior to AML reclamation, water from Iron Lake typically seeped through the north dam and flowed into a 26 hectare (65 acre) tailings pond and discharged through a 213 mm (54 in) concrete decant pipe to a basin at the toe of the south tailings dam. Water also discharged from the site via seepage from Iron Lake and the tailings basin through the lower diversion canal. A full-time caretaker controlled high flows during spring runoff from

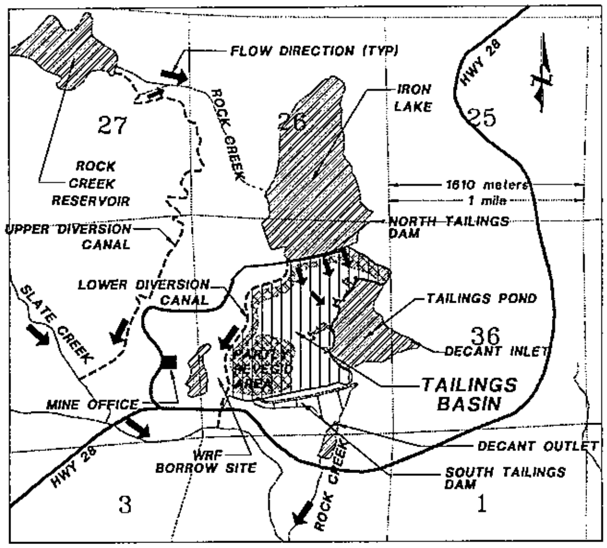

Figure 2. Pre-Reclamation Conditions

upstream of the mine and mill site through both an upper diversion canal to an off-site receiving stream as well as directly into Iron Lake. (See Figure 2)

Blowing Dust Problem

The tailings pond was drained in 1985 to implement reclamation. A large surface area of fine-grained tailings was exposed to the wind, which at high elevations in Wyoming, can be extreme. The resultant dust storms were severe, often reducing visibility to near zero on adjacent Wyoming State Highway 28. Blowing tailing dust, visible from over 81 km (50 mi.) away, was likened in appearance to a forest fire. Late in 1985, the tailings were covered by a 610 mm (2 ft.) thick layer of cobbs to stabilize the surface against the wind erosion and the tailings pond was again allowed to fill with water. A spillway and drainage ditch were constructed in 1989 to provide a discharge and outlet from Iron Lake that by-passed the tailings basin. Native earthen material excavated from the ditch, believed to be White River Formation, was spread over a portion of the tailings and revegetated. (WDEQ-LQD)

Vegetative response was initially poor, but improved to the point of self-sustenance over eight years since initial seeding.

Uncontrolled Groundwater

Portions of the tailings basin perimeter, however, were subject to the adverse influence of ground water associated with the water level in adjacent Iron Lake. The impacts were associated with severe erosion from springs that had formed along the south side of the north tailings dam and sulfate accumulation from evaporative effects. These impacts had compromised the effectiveness of the cover of cobbs material and were suppressing development of vegetation in some of the WRF-covered areas.

The water level in the tailings basin fluctuated seasonally up to about 3 meters (10 feet), restricted in part by debris accumulating on the makeshift tailings pond outlet structure. The seasonal fluctuation of water levels in the tailings basin further suppressed development of emergent and aquatic vegetation, decreasing its value as wildlife habitat.

By 1992, the potential for wind erosion of the tailings was returning.

Project Goals

The overall objective of the reclamation project was to provide geotechnically and geomorphically stable land surfaces capable of supporting a diverse productive plant community that would create an environment suitable for wildlife habitat and cattle grazing.

An additional goal was to preserve or improve the storm water protection the mine and tailings basin provided to downstream communities, especially during construction.

Preconstruction Site Investigations

Several key aspects of the site were investigated to enable the selection and design of a preferred reclamation alternative. Brief discussions of the key issues and the conclusions follow.

Geotechnical Investigation

A geotechnical investigation revealed the following:

- The South Tailings Dam had acceptable factors of safety under assumed static, pseudostatic and post earthquake (magnitude 6.1) loading conditions.

- No action appeared to be required to further stabilize the tailings facility.

- Localized liquefaction on the tailings surface was possible during construction.

Soils Investigation

The soils assessment revealed that topsoil and other surface cover materials suitable for vegetation were very limited at the Atlantic City mine site. However, the biologically "sterile" White River Formation (WRF) occurring in either stockpiled or bank sources on site was suitable as subsoil and, with organic amendments, topsoil. Mixtures of WRF and tailings could also function as subsoil. The WRF contains clay loams and clays with clay contents ranging from 29 to 45 percent (Knight Piésold LLC, 1995).

Based on water retention and other requirements, the reclamation soil profile should consist of a minimum 150 mm (6 in.) of plant growth medium containing an organic matter content of three (3%) percent over a 300 mm to 450 mm (12 to 18 in.) layer of WRF clay loam/tailings subsoil. Previous reclamation successes on the site were found to relate directly to proper construction of the soil profile described above: elimination of soil compaction by equipment, protection of plants from strong desiccating winds, and development of proper surface drainage (Knight Piésold LLC, 1995).

Studies showed that a plant growth medium could be cost-effectively produced by combining composted manure and sawdust (90% manure, 10% sawdust) with WRF in the ratio of 2.5% compost to 97.5% WRF by dry weight. If WRF was not available, compost could be amended directly into the taconite tailings; this approach has been used successfully on US EPA Superfund sites and on taconite tailings in Minnesota. (Norland, et al, 1992). The next logical alternative, importing quasi-topsoil from about 10 km (6 mi.) away, was estimated to double the cost of plant growth medium procurement.

Site Geochemistry

Geochemical analyses of the surface and ground water suggested that the accumulations of gypsum crust in the tailings basin were associated with evaporation from the tailings surface, fed by localized ground water recharge from Iron Lake and the Lower Diversion Canal (see Figure 2). It was anticipated that if the canal were abandoned and the water level in Iron Lake reduced, further accumulations of gypsum on the tailings surface would cease.

Impacts of Compost Use

The proposed use of compost as an organic amendment was met with opposition by downstream residents who expressed concern about water quality for both domestic use and for fisheries habitat. Analyses showed that:

- The water quality in Iron Lake, the Tailings Pond and the water leaving the site was virtually pristine.

- There were some seeps on the face of the south tailings dams with elevated heavy metals that were inconsistent (after considering dilution) with the existence of the trout fishery.

- Volunteer wetlands on the face and toe of the south tailings dam appeared to be sequestering heavy metals; some samples of mossy vegetation assayed 39% manganese by dry weight.

- Runoff and seepage associated with compost use was not toxic to *Ceriodaphnia* aquatic organisms as long as the suspended solids from the WRF component were controlled.

Surface Water Hydrology

The recommended major drainage system improvements for the tailings basin were:

- Construct a new, lower Iron Lake spillway and route the discharge through a rip rap channel to the tailings pond.

- Plug the existing tailings decant pipeline (in conformance with a standing court order).

- Construct the tailings pond spillway via a rip rap channel that connected to the existing Lower Diversion Canal. The spillway elevation would be controlled by the invert elevation of a culvert beneath an adjacent highway.

- Configure all spillways to maintain or improve the flood control characteristics of the site prior to reclamation.

- Backfill the Lower Diversion Canal to reduce seepage to the tailings basin surface.

- Use waste rock from the mine dumps as a durable rip rap source.

Threatened and Endangered Species

Despite the relatively pristine water quality and analyses that suggested high wetland habitat value, Iron Lake and the Tailings Pond were not being much used by waterfowl, shorebirds, and wildlife in general. The reason for this is ripe for study, but it was thought to be related to the lack of shore and near-shore vegetation which had been suppressed by extremes of water level fluctuations and the relative "newness" of the deposited tailings which approximated soil conditions soon after a glacial retreat at high altitudes (Knight Piésold LLC, 1995).

Note: Since the construction of the spillways and stabilization of the tailings pond water level, aquatic vegetation has become established and shore birds and waterfoul are now frequenting the site.

Vegetation

Lodgepole pine (*Pinus contorta*) trees had become established at previously reclaimed portions of the Atlantic City Mine by planting nursery stock. Wind shelters, both large and small, substantially improved tree survival. Limber pine (*P. flexlis*) trees had also become established in portions of the Atlantic City mine where locally collected seed was directly applied to the regraded and thinly retopsoiled surface.

These observations suggested the following revegetation recommendations:

- Local or northern latitude seed material sources should be obtained, whenever possible, due to the harsh growing conditions at the Atlantic City site.

- Construction of windbreaks with rock rubble would:

  - provide wind shelter to developing grasses, shrubs, and trees;

  - reduce sand blasting effects on planted seedlings from blowing soil and ice crystals;

  - discourage wildlife grazing on new trees that remain buried in snow banks in the revegetated areas;

  - increase effective soil moisture in localized areas by managing snow bank locations; and,

  - reduce wind erosion of valuable topsoil and surface cover materials.

Site Specific Plans

The site specific plans for reclamation needed to consider the challenges of a harsh, windy, high altitude environment, unstable geotechnical conditions, significant spring runoff flows through the site and a lack of natural topsoil. The plans included the following key physical features, some of which are shown on Figure 3:

• A rip rap lined spillway from Iron Lake to the Tailings Pond that maintained road access across the spillway with a concrete culvert,

• A rip rap lined spillway from the Tailings Pond to the final leg of the existing Lower Diversion Canal that included a wildlife-habitat-enhancing island at the spillway inlet and a width commensurate with maintaining a relatively constant pool elevation to foster shoreline plant growth,

• A backfilled Lower Diversion Canal and lowered Iron Lake pool elevation to reduce seepage into the tailings basin and thus suppress evaporite formation on the revegetated surface,

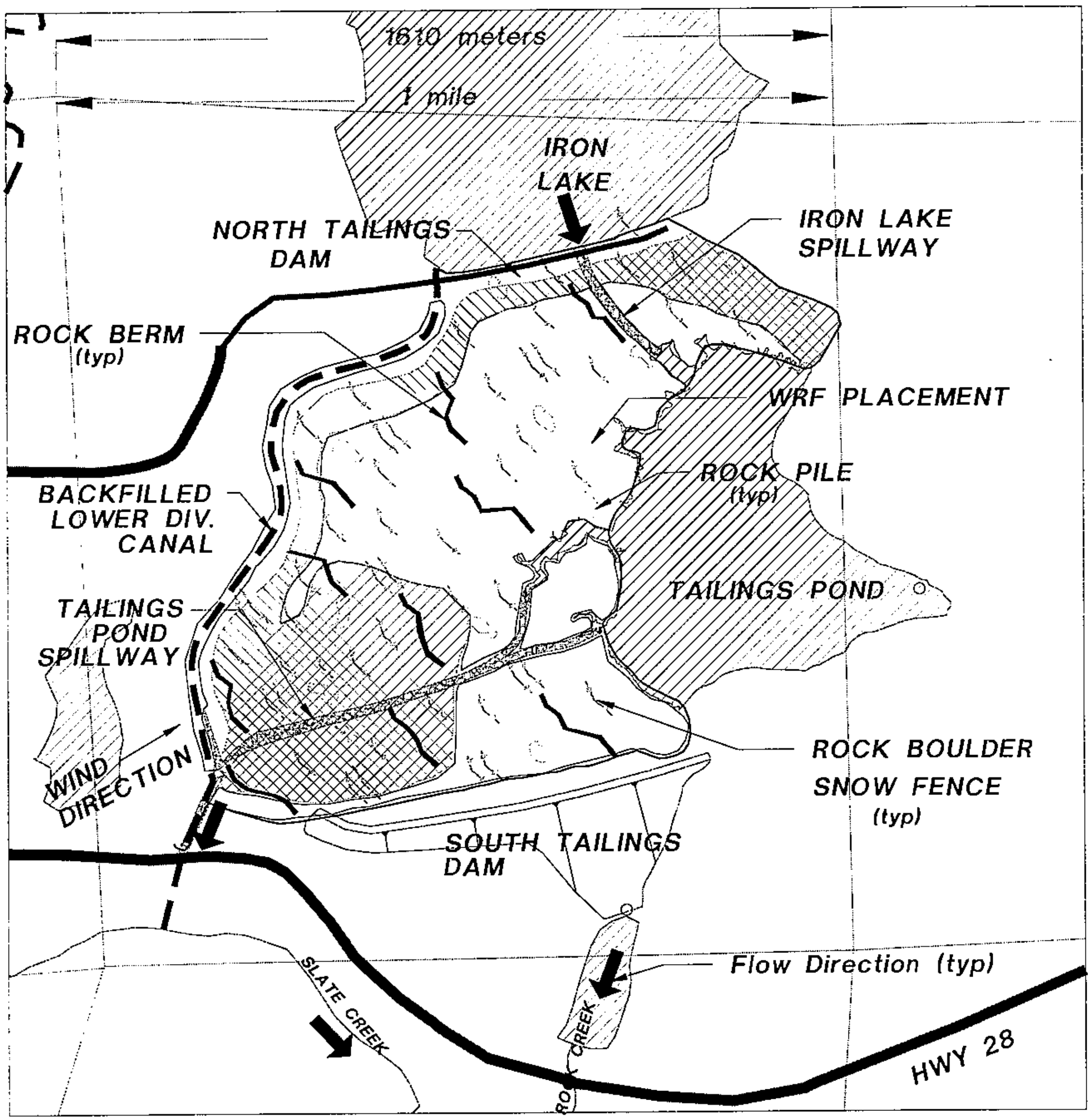

Figure 3. Reclamation Plan

• Seepage control drains to capture groundwater and further suppress evaporite formation and/or surface erosion,

• Rock berms (about 2 m high) and rock piles oriented to disrupt wind patterns across the basin, accumulate snow in their leeward shadows and protect future tree plantings,

• Vertical slat snow fences 1.3 m (4 ft) high to temporarily protect future tree plantings,

• The addition of 68 t/hectare (30 st/acre) of contractor-developed organic compost to create a surface layer of plant growth medium in a mixture of fine tailings and cobbs _or_ importing native soils that would provide a similar effect, and

• Revegetation with eight hardy grass species plus sagebrush at a rate of 40 kg PLS/hectare (35 lbs/acre), commensurate with the high altitude site with a short growing season (tree planting would occur in a subsequent construction contract). Mulch was applied at a rate of 4.5 t/hectare (2 st/acre).

It is noteworthy that the detailed plan did not include the use of WRF, either as subsoil or as a plant growth medium component. Unfortunately, the ownership of an identified stockpile of WRF came under dispute and the plans were revised to re-establish vegetation directly in the tailings/cobbs with the aid of the organic compost. At the insistence of one local landowner, however, the option of importing off-site soils was included. Although the engineer's cost estimate suggested that this option would be cost-prohibitive based on transport costs alone, it was thought that the competitive free market should drive whether compost or off-site soils would be selected. Also, the plugging of the decant pipe was deferred to a subsequent contract.

The surface of the Tailings Basin already revegetated (see Figure 2) would not be redisturbed with additional reclamation efforts except for the addition of snow-catching rock berms. The gentler-sloping (5H:1V) windward side of the southwest-facing rock berms would contain random patches of subsoil and/or topsoil to provide textural contrast as viewed by an east-bound motorist on the adjacent highway (the only viewshed in which the entire tailings basin is visible from off-site). Vegetation of these patches with grass seed was also planned.

Liquefaction of the tailings during construction was considered in the planning. To minimize the effects of this constraint, the contract was awarded at the beginning of the winter season, with the assumption that spillways would be excavated in frozen ground. Prospective bidders were advised of the potential for liquefaction and low-weight displacement/high flotation equipped vehicles were recommenced for consideration.

These key physical features were also designed to: minimize evaporative losses in the tailings pond, maximize storm water impoundment capacity in both the tailings pond and Iron Lake and eliminate the erosion and geochemical problems caused by the seepages originating in the north tailings dam and the zone downstream from the canal. The design of the permanent spillway would stabilize the pool elevation in the tailings basin which would favor emergent plant growth. The stable environment should preclude the near term and long term wind erosion of the tailings.

<u>Innovations Approved after Contract Award</u>

<u>Soil Amendments</u>

The successful contractor had won on the basis of the "composting" plant growth medium option, but had assumed importing a finished compost product from out-of-state (rather than making it locally) in preparation of the id. The bid price for composting was nearly equal to the expensive option of trucking in off-site soils. Clearly, there as an opportunity to economize and the contractor proposed a "value change proposal" or VCP at the project kick-off meeting. The essence of the VCP was to place a 300 mm (12 in) thick layer of WRF on the tailings surface and amend he organically-deficient and sterile WRF with a dry, organically-bound nitrogen fertilizer (6N-1P-1K) at a rate of .2 t/hectare (1 t/acre) and a wet organic bacterial inoculum at a rate of 47 L/hectare (5 gal/acre) to jump-start the growth of beneficial soil bacteria populations. The contractor had secured his own local source of WRF, circumventing the ownership constraint that had forced the direct seeding of the taconite tailings.

Both the WY AML program and the contractor would equally split any savings realized from implementing the VCP, estimated to be about $US 214,700, less any engineering charges required to valuate and substantiate it. This was a clear economic incentive for both parties. However, it was initially unclear if the dry organic amendment would equal the performance of the specified organic compost. As there was no opportunity or test plots to assess the VCP option, a literature search and interview program was initiated to evaluate the likely effects of VCP implementation.

Mining industry and governmental agency persons were contacted concerning the use of the following soil organic amendment products: Biosol™, Fertil-Fiber™ (both organic dry fertilizers), and Kiwi Power™, a wet bacterial inoculum. The general conclusion of ten interviews of Biosol users and four interviews of Fertil-Fiber (FF) users is that Biosol/FF has worked in a number of applications, including mining reclamation sites at high altitudes. Its application in mining reclamation appears to be relatively recent and limited to date. Therefore, it was difficult to predict its relative success over an extended period of time. Kiwi Power had been applied with FF to give it an added growth start. As the nitrogen in these products is organically bound, it is released slowly and is not washed out like inorganic fertilizers.

The theory behind the use of these amendments is that the slow release nitrogen in the solid phase allows plant growth over several growing seasons. The decaying root mass resulting from winter dormancy supposedly accumulates to become permanent organic matter available for future nitrogen cycling. The two seasons of plant activity in effect "boot strap" a nominally barren soil's organic content to the desired 2.5% to 3% mark.

An application of 2.2 t/hectare of Fertil-Fiber and 47 L/hectare of Kiwi Power was made in conjunction with the vegetation effort. Half of the Fertil-Fiber was tilled into the upper 150 mm (6 in.) of the WRF layer and the other half surface applied. These materials are typically just surface applied; the tilling component was added due to the windy climate of the site. About 58 hectare of tailings basin was treated in this manner, with adjustments made in small test plots for future evaluation. Deficiencies could be rectified in future WY AML projects at the site.

Rock Boulder Snow Fences

The original plans and specifications included approximately 3,645 m (12,000 ft) of vertical slat snow fences located randomly in 50 separate segments on the surface of the reclaimed tailings basin to enhance snow catch and shelter future plantings of limber and lodgepole pine seedlings. Due to an abundance of large boulders at the site, on the order of two meters in diameter, the contractor proposed another VCP: the substitution of rows of single or stacked boulders for the specified vertical slat snow fence. The performance of a test section

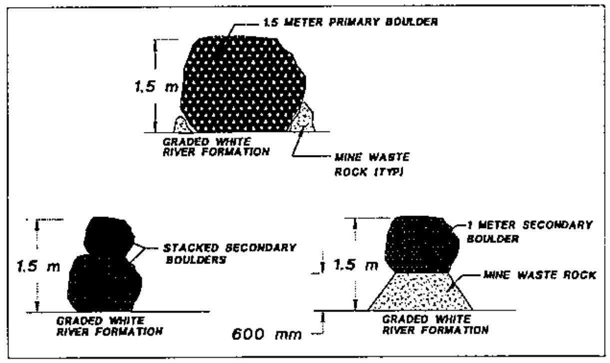

Figure 4. Rock Boulder Snow Fence

of rock boulder snow fence configuration compared favorably to a length of vertical slat snow fence over the 1997 winter season. Subsequently, three configurations of Rock Boulder Snow Fence were approved as shown on Figure 4.

This VCP resulted in the savings of about $US 22,310 which was split equally between WY AML and the contractor. The substituted installation will undoubtedly last decades longer than the temporary vertical slat snow fences specified.

Construction Schedule

The construction of the earthwork aspects of the design were completed over two construction seasons, commencing in December, 1996, including work during the winter at this high-altitude site. Revegetation efforts in the fall of 1997 were suspended because snow from an early winter storm that collected behind the rock berms and rock snow fences was slow to melt as they were designed to do. Furthermore, the increased snow catch made the site too wet the following spring to allow seeding during the normal seeding window; a fall 1998 planting was necessary. The rocky nature of the cover material prompted the development of innovative reclamation approaches, including fabricating a "rock rake" bulldozer blade and applying the Kiwi-Power organic soil amendments by aerial spraying. That aspect of the project took less than a day using a standard crop-dusting aircraft which also treated an adjacent reclaimed parcel. A randomly-configured two-acre test plot was installed to evaluate the benefits of various soil amendments as the site matures.

In 1999, native tree seed (lodgepole and limber pine) will be harvested from the conifer forest surrounding the site and greenhouse-germinated for a spring, 2001 planting in the wind shadows of rock berms and rock snow fences. The seedlings will receive a weed control plastic sheet and a mesh-style rodent barrier. In addition, a decant pipe extending from the tailings pond through one of two tailings embankments will be plugged with a cement-based grout in 1999.

Cost Analysis

The cost of the construction work was $US 2,170,154. This amount was distributed as follows:

Bid Item	Percent of Total
Mobilization/Demobilization	8.9%
Surface and Ground Water Controls	3.9%
Spillway Excavation	30.2%
Rock Berms and Rock Piles	4.3%
Revegetation (includes organic amendments)	10.1%
Misc., Sediment and Traffic Control	3.1%
White River Formation Excav. & Placement	32.0%
Rock Boulder Snow Fence	2.5%
Value Change Proposal Savings to the Contractor	5.0%

Additional construction management/inspection costs amounted to about $US 225,000 or 10.4% of construction; design costs were about $US 121,600 or 5.6% of the construction cost.

About 135 acres required seeding. The unit cost of revegetation was about $US 1,630 per acre. The combined excavation of two spillways and the placement of the White River Overburden required the handling of about 351,900 cy at a unit cost of about $US 3.56 per cy. This compares to a unit bid price of $US 3.00 per cy for the placement of Rock Berms and Rock Piles.

Assuming the construction required the remediation of 135 acres out of the 200-acre site, the unit cost of the reclamation was $US 16,075 per acre, not including engineering and construction management.

Conclusions

Despite thorough planning, reclamation efforts even conducted by state agencies can take unexpected turns. The lack of topsoil, harsh climatic conditions, and uncertain ownership situations can compound these problems. While innovative engineering solutions such as using compost as a soil amendment are available in certain situations, engineers, owners and contractors can all benefit by considering and encouraging other unique solutions.

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